SENTINEL-2 LEVEL 2A PRODUCT PROTOTYPE PROCESSOR: RESEARCH AND DESIGN ASPECTS

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The contribution covers research and development aspects concerning a Sentinel-2 atmopsheric correction processor. The Sentinel-2 multispectral sensor acquires 13 optical channels from the deep blue (0.443 μm) up to the shortwave infrared (2.19 μm) spectral range. These multispectral data allows aerosol optical thickness, water vapor, cirrus, and bottom of atmospere reflectance estimation. Sensitivity analysis given simulated and real spectral data as well as an estimation of the parameter set was done. The research outcome is documented in the algorithm theoretical basis document and implemented into an automatic batch processing chain. Scientific validation of the processor on synthetic and real data with in situ measurements finalizes the work.

Introduction

The Sentinel-2 (S2) sensor acquires optical data in 13 bands: the B1 (0.443 μm, 60m ground sampling distance (GSD)), B2 (0.49 μm, 10m GSD), B3 (0.56 μm, 10m), B4 (0.665 μm, 10m), B5 (0.705 μm, 20m), B6 (0.74 μm, 20m), B7 (0.783 μm, 20m), B8 (0.842 μm, 10m), B8a (0.865 μm, 20m), B9 (0.945 μm, 60m), B10 (1.38 μm, 60m), B11 (1.61 μm, 20m), and the B12 (2.19 μm, 20m).

The products to be estimated by the Level 2A chain are the aerosol optical thickness (AOT) (estimated by the dense dark vegetation method (DDV) [1] and the spectral data acquired in the blue (B1 or B2), red (B4), and the short wave infrared (SWIR) (B11 or B12) bands); water vapor (WV) (estimated by the Atmospheric Pre-Corrected Differential Absorption (APDA) method [2] given the reference (B8a) and measurement (B9) bands); and cirrus corrected data (band B10 is employed).

I. Sensitivity analysis

A top of canopy (TOC) database consisting of several landcover classes was composed from synthetic (generated by PROSAIL and HYSIMCAR models) and real (ASTER spectra library) data [3]. The spectra are generated for 1 nm resolution for the 0.4-2.5 μm spectral range. DDV spectra are among the spectra. The goal is: estimation of band correlation factors; threshold level for the DDV pixels selection; best S2 spectral bands for AOT retrieval. The reference and worst case data for different S2 channel response functions are analyzed.

The top of atmospere (TOA) database is generated from the TOC spectra. The MODTRAN code [4] is employed to simulate the propagation of the radiance in the atmosphere (standard settings: midlatitude summer, ozone: 331 DU, CO2: 400 ppmV, trace gases are with the standard settings). MODTRAN guarantees a high accuracy of the estimated radiative transfer variables. A variation of the employed parameter set such as the solar and view geometry, atmosphere model, water vapor, etc. is given in Table 1 (VZA is the view zenith (off-nadir) angle, SZA is the solar zenith (off-nadir) angle, RAA is the relative azimuth angle, ELE is the elevation). The 1 nm TOA spectra are convolved with S2 bands response functions (reference and worst cases). A sensitivity analysis is carried out on the TOA data.

Table 1 – Parmeter set variation for the TOA spectra generation

AOT	model	WV, cm	SZA,°	VZA,°	RAA,°	ELE, km
0.6598, 0.4616, 0.3237, 0.2037, 0.0777	rural	1, 2.9	30, 60	0	back.	0
0.6598, 0.4616, 0.3237, 0.2037	rural, urban, maritime	1	30	10	back.	0
0.3486, 0.2472, 0.1578, 0.0621	rural	1	30, 60	10	back.	1.5
0.4616, 0.3237, 0.2037, 0.0777	rural	1	30	0, 10	forw. and back.	0

For the DDV pixels selection there is no significant difference between the reference and worst cases. Iterative TOC reflectance thresholds on the SWIR 2.2 μm band are used: 5%, 10%, and 12%. The 5% threshold allows selection of only coniferous vegetation, increase of the threshold up to 12% selects the other types of the DDV vegetation or dark soil.

The AOT estimation sensitivity analysis is carried out for the following band combinations: B1/B4, B2/B4, B1/B11, B2/B11, B1/B12, B2/B12, MEAN(B1, B2)/B4, MEAN(B1, B2)/B11, and MEAN(B1, B2)/B12 given the AOT value (atmosphere type: rural, WV: 1.0 cm, ELE: sea level, VZA: 0°, SZA: 30°). The analysis is constrained only for the DDV spectra. No significant difference between the reference and worst case results was found. The B2/B11, B4/B11, and B4/B12 combinations were selected and recommended and these are in agreement with the state of the art knowledge [1].

II. Water vapor estimation

The S2 B8a 0.865 μm (reference) and B9 0.945 μm (measurement) bands are employed for the WV estimation with the APDA model.

$$R_{APDA}(\rho, u) = \frac{L_{0.945}(\rho_{0.945}, u) - L_{p,0.945}(u)}{L_{0.865}(\rho_{0.865}, u) - L_{p,0.865}(u)}, \tag{1}$$

where the L is the TOA radiance, the L_p is the path radiance, u is the water vapor column, α and β are the fit coefficients.

$$R_{APDA}(u) = exp(-\alpha + \beta\sqrt{u}). \tag{2}$$

$$u = \left(\frac{\alpha + ln(R_{APDA})}{\beta}\right)^2. \tag{3}$$

III. Cirrus removal

Cirrus clouds exist in the upper troposphere and lower stratosphere. Cirrus affects the visible and near infrared as well as SWIR range. The narrow 1.38 μm band is able to detect cirrus clouds. If a correlation of the cirrus signal at 1.38 μm and the wavelengths in the visible and near infrared (VNIR) and SWIR region can be found (DDV pixels are used), then the cirrus contribution can be removed from the radiance signal to obtain a cirrus-corrected scene. Since the S2 channels have channel-dependent parallax angles, an accurate cirrus correction according to the method of [5, 6] is not possible, but this method can be used for an approximate correction.

IV. L2A Software

The L2A chain is based on the ATCOR (ATmospheric CORrection) software [7]. A granule size acquired by the S2 is approx. 100×100 km and the corresponding VZA and SZA variations of the atmospheric RT functions are taken into account.

Since the S2 bands are acquired with three GSDs (10, 20, and 60m) the AOT and WV maps are estimated on 20m data (the 10 and 60m bands are interpolated to 20m) and BOA reflectance for 20m bands is estimated. Then the AOT and WV maps are interpolated to the 10 and 60m and the 10 and 60m bands reflectance is estimated. Such interpolation is safe since the AOT and WV maps are smooth.

V. Software Verification and Validation

The required relative error for the AOT, WV, and cirrus correction is 10%. However, for cirrus detection and the BOA reflectance the relative error is 5%. The AOT estimation is validated on the simulated TOA/BOA spectra as well as real AERONET measurements with corresponding Landsat 8 data. Since the study was carried out before the S2 launch we used Landsat 8 scenes as the best substitute for the S2. Therefore cirrus cloud correction is validated given a pair of Landsat 8 scenes acquired for the same geographic area (one scene is with cirrus and the other is cirrus free). BOA reflectance data are analyzed by basic statistics, relative difference histograms, histogram distance, spectra profiles distance. A comparison of the BOA reflectance with an alternative atmospheric correction chain (FLAASH) was performed, leading to a high agreement in the reflectance data. Interface tests are also performed.

VI. Concluding remarks

The developed processing chain fulfills the high accuracy requirements on synthetic (BOA and TOA spectra) and real data (Landsat 8 and AERONET). The software is already successfully tested on comissioning data.

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